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Study On the Effect of Stone, Dust, Ceramic Dust and Brick Dust as Fillers on the Strength, Physical and Durability Properties of Bituminous Concrete (BC –II) Mix

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Abstract

The objective of this study was to investigate and evaluate effects of mineral fillers on fatigue properties of hot mix asphalt (HMA) mixtures. Several tests such as: Marshal Stability, Indirect tensile strength and fatigue test were conducted. The fatigue life of mixtures has been evaluated based on the initial stiffness modulus at 20%, 30% and 40% stress levels. Using of waste from special industries is current scenario, that's why industrial wastes like fly ash, pond ash, GGBS, copper slag, marble dust etc. are being used in bituminous mixes. In the existing study, an attempt is made to use stone dust, ceramic dust and brick dust as filler in bituminous concrete mix. BC mix with ceramic dust has higher Marshall Stability value of 1310 kg, which is higher than BC mix with Stone dust and brick dust with stability 1220 and 1297 kg respectively.

Tensile stresses get induced at the bottom of bituminous concrete layer due to wheel load movements over the surface of the flexible pavement. To examine the tensile strength of the bituminous concrete, Indirect Tensile Strength (ITS) check is carried out at 25 °C. Since the pavement temperature isn't always regular, it is necessary to assess the strength attributes of bituminous blends at various temperatures. The stiffness of the mixture may be advanced by using use of suitable fillers. In the existing study, an attempt is made to evaluate the temperature effects on ITS of bituminous mixes when stone dust, ceramic dust and brick dust are used as fillers at 20°, 30°, 40° and 50°C.

The results show that fatigue life of asphalt mixtures prepared with ceramic dust as filler is longer than HMA blends with stone dust and brick dust as fillers. Also, it was seen that industrial waste addition leads to relative increase in indirect tensile strength and resilient modulus of asphalt mixtures. Finally, based on experimental results, a model is proposed to describe the fatigue behaviour of asphalt mixtures containing various fillers.

Keywords: Bituminous Concrete; Marshall Stability; ITS; Fatigue life; Fillers

1. Introduction

The fast development of urban communities brought about a great deal of transportation. In tropical nations, the pavement surface temperature escalates to a great extent on black top pavements than the white top pavements. Different materials, for example, concrete, lime, rock powder, stone clean and fine sand are typically utilized as filler in bituminous blends. The utilization of waste materials as filler in black-top blend has been the concentration of a few research endeavours in the course of recent years. It was demonstrated in various research findings that these sorts of reuse filler could be utilized as a part of black-top blend and gave enhanced execution. So the present review has been taken keeping in mind the end goal to research the conduct of bituminous blends with various sorts of filler materials locally accessible. The investigation of ceramic waste can decide if it is feasible to be utilized as a part of black-top blend. Also, it might decrease the cost of road development. Other than that, this review will expand the mindfulness about the present issue which is caused by transfer modern waste.

2. Objectives of the study

i. To study the properties of bitumen, aggregates and mineral fillers used for the present study.

ii. To design the bituminous concrete mix using Marshall method of mix design and analyse the Marshall properties for suitability of stone dust, ceramic dust and brick dust

iii. To conduct and compare the Indirect Tensile strength test on Marshall specimens and to determine Tensile strength ratio of bituminous concrete mix with stone dust, ceramic dust and brick dust as fillers at 20°, 30°, 40°, 50° C.

iv. To Conduct the fatigue test on Marshall specimens with stone dust, ceramic dust and brick dust as fillers at 20%, 30%and 40% stress level

3. Experimental Investigations

3.1 Materials and their physical properties

3.1.1. Aggregates

The aggregates were procured from a local quarry named Cauvery Asphalts at Bengaluru in the state of Karnataka and were tested to check its suitability to be used in the study as per MoRT&H 5th revision specifications for BC Mix Grade II The results of the same are projected in Table 3.1. Table 3.2 indicates the recommended gradation limits specified by MoRT&H 5th revision specifications for BC Mix Grade II.

3.1.2. Bitumen

Viscosity Grade- 30 Bitumen was obtained from Cauvery Asphalts at Bengaluru in the state of Karnataka and the test results satisfying the specifications as per MoRT&H 4th revision for BC Mix Grade II are presented in the Table 3.3

3.1.3. Filler

Stone Dust was obtained from a local quarry at Bengaluru in the state of Karnataka. Brick Dust was obtained by pulverizing the brick bats at Department of Civil Engineering, MSRUAS, Bengaluru. The Ceramic Dust was provided by H&R Johnson Tiles, Kunigal Plant, Tumkur. The Specific Gravities of the fillers used for the study are indicated in Table 3.4.

Table 3.1 Test results of Aggregates

Aggregate Test	Standards followed	Test Result	Requirements as per Table 500-18 of MoRT&H (5th-Revision) Specifications
Aggregate impact value (%)	IS:2386-4	22.50	Max 24%
Los Angeles abrasion value (%)	IS:2386-4	20.10	Max 30%
Flakiness and Elongation Index (Combined) (%)	IS:2386-1	25.23	Max 30%
Water absorption (%)	IS:2386-3	0.35	Max 2%
Aggregate specific Gravity			
Coarse aggregates	IS:2386-7	2.60	---
Fine aggregates	IS:2386-7	2.63	---

Table 3.2 Aggregate gradation for Bituminous Concrete mix (Grade-II) as per MORT&H (5th-Revision) specifications

Sieve Size in mm	% Passing (Specified)	% Passing (Mid Limit)
19	100	100
13.2	90-100	95
9.5	70-88	79
4.75	53-71	62
2.36	42-58	50
1.18	34-48	41
0.6	26-38	32
0.3	18-28	23
0.15	12-20	16
0.075	4-10	7

Table 3.3 Binder Test results

Tests on Bitumen as per IS:1203-1978	Results	Requirements as per IS 73-2013
	VG-30	
Penetration at 25°C	65	Min 45
Softening point (Ring & Ball), °C	52	Min 47
Flash point, °C	240	Min 220
Ductility @27 °C ,cm	70	Min 40
Specific Gravity	1.01	---

Table 3.4 Test results of Specific Gravity test on Mineral Fillers as per IS: 2386-7

Filler	Specific gravity
Stone dust	2.63
Ceramic dust	2.65
Brick dust	2.58

3.2. Indirect Tensile Strength (ITS)

Indirect Tensile Strength Testis a pointer of quality and adherence against exhaustion, temperature breaking and rutting. Weakness life of the bituminous blend relies on upon ITS esteem. ITS value fills in as the reason for touching base at stress proportion for completing weakness tests. In this test, compressive load is applied through a vertical strip on Marshall Specimen. Because of the geometry of the specimen, tractable burdens are created and the specimen flops by part into two parts. The heap at failure is recorded and ITS is processed utilizing the condition:

$$Sx = \frac{2P}{\pi DT}$$

Where,

Sx = Horizontal tensile strength or tensile stress, N/mm^2

P = Failure Load in N

D= Diameter of the specimen in mm

T = Height of the specimen in mm

3.3. Tensile Strength Ratio (TSR)

Dampness harm in bituminous blends alludes to the loss of serviceability because of the nearness of dampness. The degree of dampness harm is known as the dampness defenselessness. The ITS test is an execution test which is regularly used to assess the dampness defenselessness of a bituminous blend. Rigidity proportion (TSR) is a measure of water affectability. It is the proportion of the rigidity of water molded example, (ITS wet, 60°C, and 24 h) to the elasticity of unconditioned example (ITS dry) which is communicated as a rate. A higher TSR esteem normally shows that the blend will perform well with a decent imperviousness to dampness harm. The higher the TSR esteem, the lesser will be the quality lessening by the water drenching condition, or the more water-safe it will be. The Indirect Tensile Test is a standout amongst the most well-known tests utilized for hot bituminous blend portrayal in assessing asphalt structures.

4. Analysis of Data

4.1 Marshall stability test

Marshall Stability Test was conducted on bituminous concrete mix (GR-II) with Stone Dust (2%), Ceramic dust (2%), Brick dust (2%) as fillers and neat (VG-30) bitumen to determine optimum bitumen content (OBC), Marshall Stability Value, Flow Value, Bulk density, Total Air voids, Voids in Mineral Aggregates and Voids Filled with Bitumen respectively. The relationship of binder content v/s Marshall Properties and graphical comparison between Stone dust, Ceramic dust and Brick dust is shown in Figure 4.1

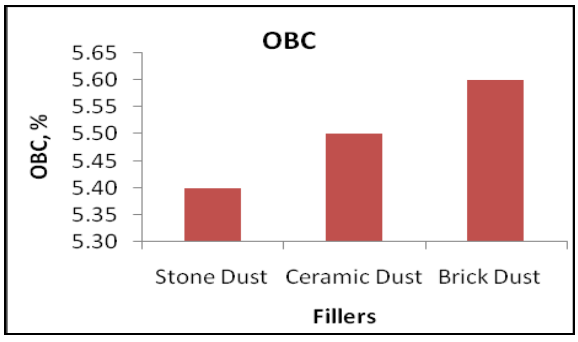

Fig 4.1 (a)

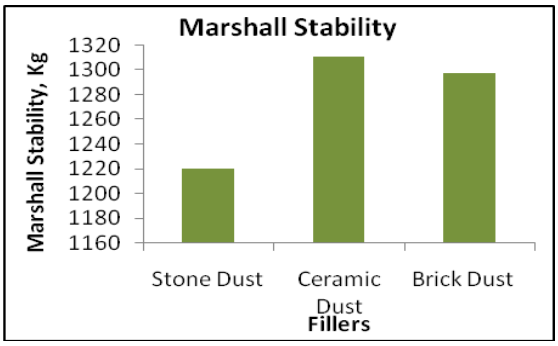

Fig 4.1 (b)

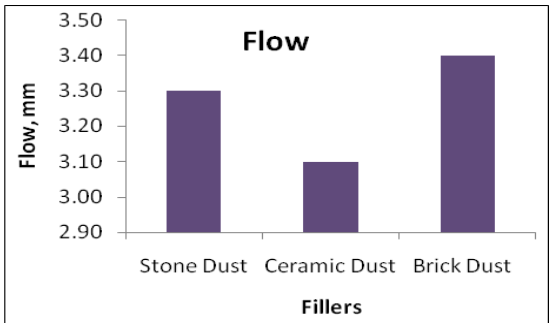

Fig 4.1 (c)

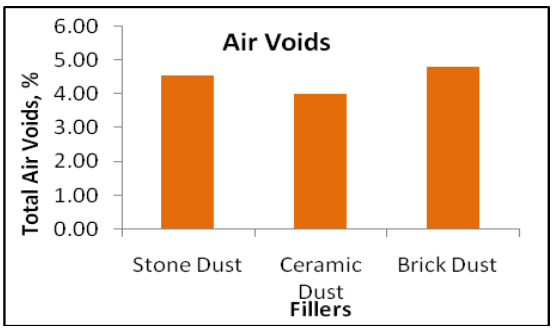

Fig 4.1 (d)

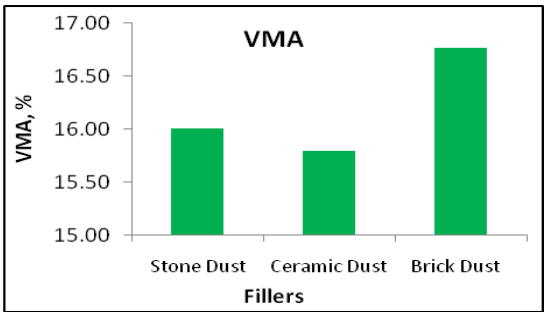

Fig 4.1 (e)

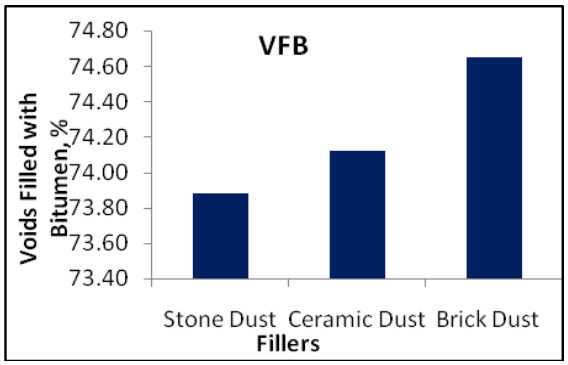

Fig 4.1 (f)

Figure 4.1 (a) to (f) Comparison of Relationship of Marshall Properties v/s Bitumen content with Stone dust, Ceramic dust and Brick dust as fillers

4.2 Indirect Tensile strength (ITS) and Tensile strength ratio (TSR)

To evaluate the effect of temperature on bituminous concrete mix, the ITS was selected as the criteria in this study. Tensile strength ratio is determined to find the moisture susceptibility of bituminous concrete mix. ITS and TSR tests were conducted at four different temperatures on bituminous concrete mix with three fillers viz; stone dust, ceramic dust and brick dust. The test temperatures were 20^0, 30^0, 40^0, and 50^0C. Presented in figure 4.2 and 4.3

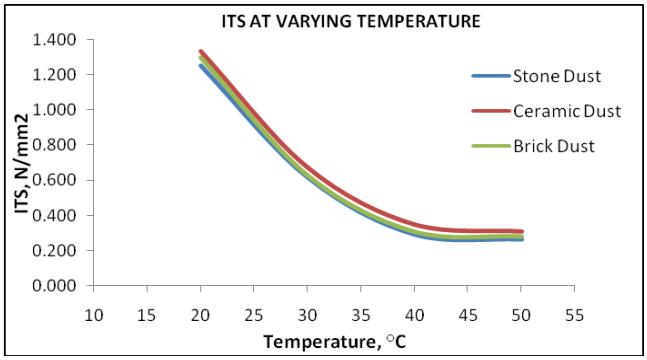

Fig 4.2 Variation of ITS with Temperature

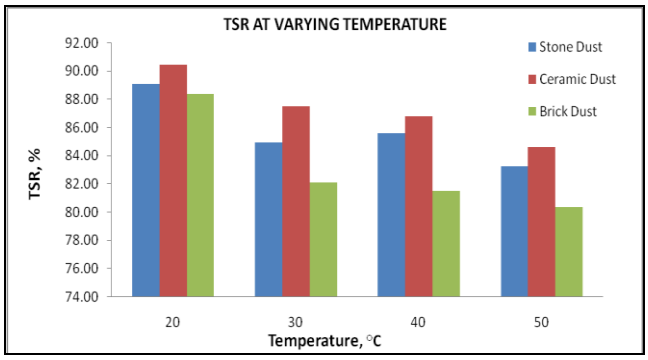

Fig 4.3 Variation of TSR with Temperature

4.3 Fatigue test of bituminous concrete mix

To evaluate the fatigue life on bituminous concrete mix, the fatigue test was selected as the criteria in this study. Fatigue tests were conducted at four different stress levels. The stress level is dependent on the indirect tensile strength value on bituminous concrete mix with three fillers viz; stone dust, ceramic dust and brick dust. The stress levels chosen were 20, 30, and 40% of the ITS value. Fatigue test is done to find the fatigue life of bituminous concrete mix. The test results for the bituminous concrete mix specimens prepared using stone dust, ceramic dust and brick dust as filler at OBC are presented in figure 4.4

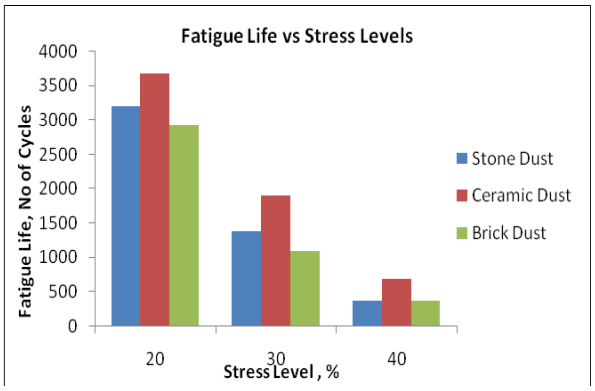

Fig 4.4(a) Variation of fatigue vs stress level

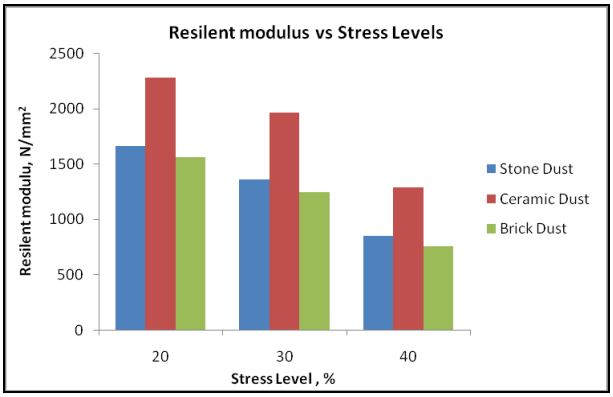

Fig 4.4(b) Variation of Resilent modulus vs Stress level

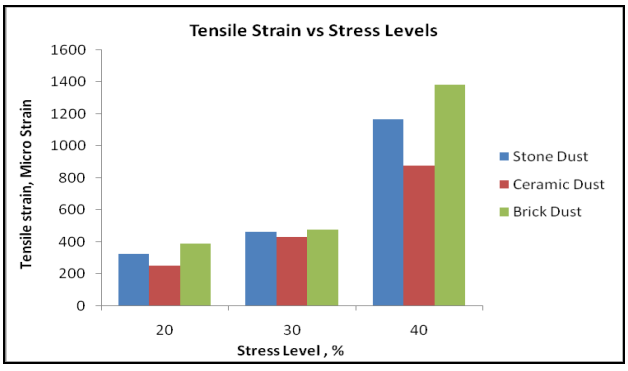

Fig 4.4(c) Variation of Tensile Strain vs Stress level

5. Discussions and Conclusions

5.1 Marshall Test

1. Optimum Bitumen Content for Bituminous Concrete mix prepared using stone dust, ceramic dust and brick dust as fillers are 5.40%, 5.50% and 5.60% respectively.
2. Marshall Stability value at Optimum Bitumen Content for Bituminous Concrete mix prepared using stone dust, ceramic dust and brick dust are 1220, 1310 and 1297 kg respectively. BC Mix prepared with ceramic dust is superior.
3. Flow value at Optimum Bitumen Content for Bituminous Concrete mix prepared using stone dust, ceramic dust and brick dust are 3.30 mm, 3.10 mm and 3.40 mm respectively. With increase in the fineness of the filler, flow reduces.
4. The Percent Air Voids at Optimum Bitumen Content for Bituminous Concrete mix prepared using stone dust; ceramic dust and brick dust are 4.52%, 3.98 % and 4.78% respectively. As ceramic dust is finer, the mix is more closely packed than stone dust and brick dust.
5. The Percent Voids Filled with Bitumen at Optimum Bitumen Content for Bituminous Concrete mix prepared using stone dust, ceramic dust and brick dust are 73.88%, 74.12% and 74.65% respectively.

5.2 Indirect Tensile Strength (ITS) Test

ITS at various temperatures is done to simulate the field conditions, where the BC mix is subjected to varying ambient temperatures.

- ITS of bituminous concrete with stone dust as filler at 20, 30, 40, 50^{0}C are 1.253, 0.617, 0.295, 0.266 N/mm^2 respectively.
- ITS of bituminous concrete with ceramic dust as filler at 20, 30, 40, 50 ^{0}C are 1.332, 0.673, 0.351, 0.308 N/mm^2 respectively.
- ITS of bituminous concrete with brick dust as filler at 20, 30, 40, 50^{0}C are 1.299, 0.631, 0.308, 0.280 N/mm^2 respectively.

5.3 Results of TSR

Tensile strength test gives a measure of moisture susceptibility of the mix.

- TSR of bituminous concrete with stone dust as filler at 20, 30, 40, 50 ^{0}C are 89.12, 85.57, 84.95, 83.27% respectively.
- TSR of bituminous concrete with ceramic dust as filler at 20, 30, 40, 50 ^{0}C are 90.49, 87.50, 86.78, 84.64% respectively.
- TSR of bituminous concrete with brick dust as filler at 20, 30, 40, 50 ^{0}C are 88.39, 82.08, 81.50, 80.34% respectively.

5.4 Results of Fatigue Test

Resilient Modulus

- The Resilient Modulus of BC mix with stone dust at 20, 30, 40 % stress levels are 1644.835, 1357.906 and 743.279 N/mm^2 respectively.
- The Resilient Modulus of BC mix with ceramic dust at 20, 30, 40 % stress levels are 2263.954, 1963.801 and 1275.869 N/mm^2 respectively.
- The Resilient Modulus of BC mix with brick dust at 20, 30, 40 % stress levels are 1540.655, 1265.391 and 831.006 N/mm^2 respectively

Tensile Strain

- The tensile strain of BC mix with stone dust at 20, 30, 40 % stress levels are 319.016, 459.880, 1375.910 micro strains respectively.
- The tensile strain of BC mix with ceramic dust at 20, 30, 40 % stress levels are 248.195, 422.593, 871.287 micro strains respectively.
- The tensile strain of BC mix with brick dust at 20, 30, 40 % stress levels are 386.962, 472.309, 1162.131 micro strains respectively Fatigue cycle
- The fatigue life of BC mix with stone dust at 20, 30, 40 % stress levels are 3204, 1382, 382 number of cycle respectively.
- The fatigue life of BC mix with ceramic dust at 20, 30, 40 % stress levels are 3687, 1901, 697 number of cycle respectively.
- The fatigue life of BC mix with brick dust at 20, 30, 40 % stress levels are 2928, 1103, 371 number of cycle respectively

6 Conclusions

- Optimum bitumen content required is more for bituminous mix prepared using brick dust as filler than that of stone dust and ceramic dust as fillers.
- Based on the Marshall properties, it is indicative that bituminous concrete mix prepared using ceramic dust as mineral filler is superior than mix prepared using stone dust and brick dust as filler materials.
- With increase in temperature there is reduction in the ITS and TSR values irrespective of the filler.
- Bituminous concrete with ceramic dust as filler has greater resistance to moisture in comparison with stone dust and brick dust.

It is also seen that BC mix with ceramic dust has higher MR and lower strain.

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